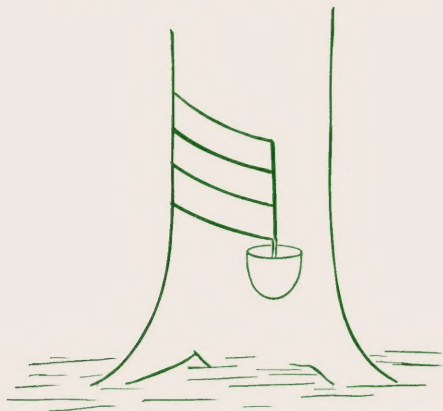


THINGS

of science



NATURAL RUBBER

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NATURAL RUBBER

The full impact of the importance of rubber in today's world is felt when we observe the many vehicles traveling incessantly along our highways or see the constant stream of airplanes taking off or landing at the airports—all of them with wheels encircled by rubber tires. Transportation, and as a consequence our way of life, is dependent upon this elastic substance and would be greatly hampered without it.

Although we now cannot conceive of a life without rubber tires to take us smoothly from place to place, the first specimens of rubber introduced to Western Civilization were regarded only as curiosities. Columbus, during his second visit to the New World, noticed the Haitians playing with a ball made from the gum of a tree and in 1496 when he returned to Spain, took samples of these bouncing balls back to Queen Isabella. But the intrinsic nature of the unusual substance went unnoticed for almost two centuries.

Little did the people then suspect how indispensable rubber would one day become nor how much man would come to rely upon it because of its distinctive properties.

The most important use of rubber

today is in the manufacture of tires, almost 68% of the total production of natural rubber being used for this purpose in the United States. But its many diverse properties make rubber useful in countless varieties of applications.

With the materials in this unit you will learn about some of these interesting properties and how they are applied.

First identify your specimens.

LATEX—White liquid in vial.

TIRE CARCASS—Black strip of flexible material used as tire ply stock in the manufacture of automobile tires.

LATEX THREAD—White strip made up of fine lengths of latex thread.

BALLOON—Made from natural rubber.

FOAM UNDERLAY CARPET—Strip of carpeting with foamed rubber underlay.

RUBBER BAND—Made of natural rubber.

SMOKED RUBBER—Ribbed Smoked Sheet (RSS); in plastic bag marked "RRIM RSS No. 1"; strip of crude natural rubber smoked to dry and to preserve it.

STANDARD MALAYSIAN RUBBER (SMR)—In bag marked "RRIM SMR 5L"; raw rubber granules dehydrated and compressed for shipping.

The materials for this unit were ob-

tained through the cooperation of The Malaysian Rubber Bureau/USA, a unit of the Malaysian Rubber Research and Development Board.

COLLECTING LATEX

The source of rubber is latex, a whitish serum produced in rubber trees. There are many plants that produce latex, but the only species that is of real economic importance is the *Hevea brasiliensis*. This rubber tree is the most adaptable to cultivation and provides the greatest yield of latex.

Hevea grows wild in South America, especially in the hot and humid rain forests of the Amazon. The early Amazonian Indians were the first to make rubber out of latex, collecting the milky sap and drying it on sticks over smoky fires to harden. They called the substance "cachuc," meaning weeping wood, and molded from it such things as rubber shoes and balls.

The English word "rubber" for cachuc was originated by the famous English clergyman-chemist, Priestly. In his book published in 1770 he mentioned that he had seen a substance from the West Indies that could rub out the marks of a black lead pencil and called it "Indian rubber." Since then the material has been referred to as rubber although its use for

this purpose is only minor.

Until about the middle of the nineteenth century rubber was not very useful in a practical way since its nature was influenced by temperature, becoming sticky in hot weather and brittle when cold. But in 1839 Charles Goodyear discovered that by heating rubber with sulfur it could be made to withstand a wide range of temperatures. About the same time, Hancock in England devised a similar method for treating rubber. This process developed by these two scientists is known as vulcanization and changed the course of rubber history.

With the discovery of vulcanization, the demand for rubber grew rapidly. The rubber tree requires a hot, wet climate for optimum production, but gathering latex was very difficult in the dense jungles of South America where the rubber trees grew. Efforts were made to cultivate these trees in a more accessible environment. The equatorial climate of Southeast Asia seemed ideally suited for the growth of rubber trees, and after many years of experimentation, *Hevea brasiliensis* was successfully grown in Ceylon and Malaya. Now, although the rubber tree is a native of South America, over 90% of the world's supply of natural rubber comes from Malaya and other countries of Southeast Asia.

Experiment 1. Examine the milky white fluid in the vial. This latex was obtained from the rubber tree *Hevea brasiliensis* grown in Malaya, and was contributed for use in this unit by the Malaysian Rubber Bureau/USA.

Latex is secreted by the cells in the tissues of the rubber tree and is carried in the capillary tubes or latex vessels that are branched and continuous throughout the living part of the plant. The exact function of latex in the physiology of the tree is still not known. In the bark just outside the cambium or green growing layer, the latex vessels come together and form concentric layers about 3 mm thick of almost vertically arranged bundles, just slightly inclined from left to right (about 5 degrees).

To collect the latex an incision is made about 1 mm deep—almost, but not quite through—the bark of the tree with a special V-shaped knife. The cut is usually sloped down from left to right at about 30 to 40 degrees to the horizontal. The lower end slopes into a vertical channel with a spout attached. A cup is mounted beneath the spout to catch the latex. The gathering of latex in this manner is referred to as tapping.

Tapping is usually carried out in the early hours of the morning because latex flows best then. The flow usually lasts

from two to five hours. At the end of the tapping period, the latex remaining in the grooves coagulates sealing them.

After the first tapping, latex is quickly replenished by the tree and when the wound is reopened for the next collection, the amount of latex obtained is greater. This reaction is known as wound response. Thus, a continuous supply of latex can be obtained from the same tree for many years. Usually a tree is tapped every other day. However, new high-yield varieties have been developed that require tapping only about once a week, while still producing the same total amount.

Each time the tree is to be tapped, the coagulated material is removed and a very fine sliver of the bark, about 1 mm thick, is cut away to reopen the vessels. This procedure is repeated systematically down the bark to a specified distance. The bark that has been cut away gradually regenerates and the whole process can be repeated over and over again for the yielding life of the tree, about 25 to 30 years.

The latex as it flows from the trees is milky white like your sample, but when exposed to the air and allowed to dry it darkens, turning a yellowish-brown color as a result of enzyme action on the protein in the rubber.

Experiment 2. Place a drop of your latex on a piece of wax paper or a dish and allow it to remain exposed a half hour or more. Does it turn yellow and then darken to a brown color and gradually harden? As it dries latex also hardens or coagulates. Feel the coagulated drop. Is it hard but still flexible and elastic?

After collection, the latex is strained of particles of bark and other foreign material at a central collection station and diluted with water. About 15% of the latex is retained in liquid form and concentrated by centrifugation for various uses by manufacturers and the rest is usually coagulated with weak organic acid. Some of the latex may be collected in plastic bags instead of open cups and then allowed to coagulate naturally or by bacterial action. Latex from the tree contains about 30 to 35% rubber solids and the rest is water.

Because latex is sticky and viscous, some of it will spill onto the bark and on the ground where it coagulates. Also some latex always remains in the tapping cup after it has been emptied coagulating there. These coagulated materials are gathered and processed into lower grades of latex as natural coagulum. The former is called "tree lace," and the latter is "cup lump."

The liquid latex collected in the cups

or plastic bags is called whole field latex and is classified as the highest grade.

NOTE: Be sure to cover the vial of latex tightly after each experiment to prevent the latex from coagulating and drying. Store the vial in a cool place out of the direct sunlight, placing it upside down to prevent air from seeping into the vial.

LIQUID LATEX

Latex has many properties that make it suitable for use directly from its liquid state.

Experiment 3. Look closely at the liquid latex. Hold it up to the light. You will find that it is opaque. Latex is an emulsion of about 30 to 35% rubber particles in water with a small amount of organic and inorganic substances in solution. After collection it is treated with chemicals to prevent it from coagulating during storage, to bleach the rubber and to prevent mildew or fungus growth.

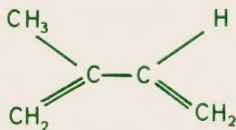
Place a drop of the latex on your index finger and then press it down with your thumb. Is it sticky? This stickiness of latex is very useful in making various types of adhesives. The pressure sensitive adhesive used on self-sealing envelopes is made of natural latex; so are many of the adhesives used in making shoes.

Experiment 4. Now rub the drop between your thumb and finger and note that as the water disappears you obtain small lumps or fine threads of white flexible material. These are formed by the coagulation of the rubber particles. Pull on the threads. Are they elastic? Drop the pellets. Do they bounce? Press one of the pellets between your fingers. Note that it is flexible and when released returns to its original shape.

This elasticity and flexibility of rubber is its most important characteristic.

Chemically natural rubber is a hydrocarbon. A hydrocarbon is a compound that contains only two elements, carbon (C) and hydrogen (H).

The hydrocarbon composing rubber is isoprene (C_5H_8) containing five carbon atoms and eight hydrogen atoms. Its structural formula is shown below.



cis-isoprene monomer

Fig. 1

This arrangement of the atoms is the cis configuration and is the form characteristic of the rubber molecule. Single molecules of such hydrocarbons are called monomers. Monomers have a tendency to become linked together in long chains to form large molecules or macromolecules. Such macromolecules are called polymers (poly- meaning many.)

The rubber hydrocarbon is the polymer cis-polyisoprene (Fig. 2) composed of thousands of units of isoprene linked together in a very regular pattern.

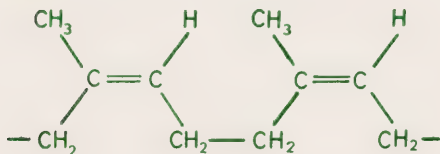


Fig. 2

The letter n in the formula stands for an indefinite number, ranging mostly from five to six thousand.

The long chains of these flexible rubber molecules are not all the same length

and the molecular weights of the individual polymer chains vary widely.

When rubber is vulcanized, the polyisoprene molecules become crosslinked or become attached to each other by molecular bridges at certain points along their lengths. Crosslinking is a very complicated process and is usually brought about by heating the raw rubber with sulfur. But there are many other methods of vulcanization depending upon the properties desired in the final product.

Crosslinking is an essential process in the manufacture of rubber and is necessary to provide the material with the properties that give it its special characteristics. The crosslinked molecules form a three-dimensional network, but little is still known of its exact structure. A diagrammatic representation of crosslinking is shown in Figure 3.

Crosslinking causes rubber to become more flexible and its elasticity can be modified by controlling the number of crosslinks produced. As the extent of crosslinking is increased the less elastic the rubber becomes. Thus rubber products of high elasticity like the latex thread in your unit can be compounded as well as hard rigid material like ebonite, or hard rubber.

Experiment 5. Take a drop of your liquid latex and roll it into a fine thread.



Fig. 3

Now stretch it gently. Note that it is elastic but breaks readily under slight tension. Twist it and it will break apart.

Remove a single length of thread from your latex ribbon. Note how fine it is. Stretch it and observe how far it can be stretched without breaking. Twist it. Does it break? This thread has been vulcanized and as you can see it is much stronger and much more elastic than the thread you made from raw latex.

To obtain high elasticity, the molecules must be held together by the molecular bridges created by vulcanization. This crosslinking prevents the rubber molecules from slipping past each other and breaking apart when the rubber is

stretched.

Experiment 6. Cut a dozen or so irregular lengths of string and arrange them parallel to each other with their ends overlapping (Fig. 4). The pieces of string

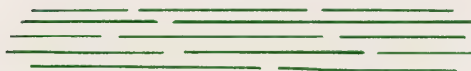


Fig. 4

represent long chain polyisoprene molecules.

Pull the string molecules away from the center from each end. As you do so, note that they slide past each other and soon wide spaces will appear where no molecules are present. Uncrosslinked molecules of raw rubber, like those in the thread you made from your liquid latex, behave in a similar manner, sliding by each other when the rubber is stretched. The rubber breaks or tears where the open spaces occur.

Now join the strings together like the illustration in Figure 3. By tying the strings together you have formed a network of crosslinked molecules. Now pull the network from each end. Because they are joined, the molecules do not separate but stretch like a net or brushpile becom-

ing narrower as the tension is increased.

Pull on your latex thread and notice that the more it is stretched the narrower it becomes.

Vulcanization imparts strength and resistance to shearing to rubber and increases its elasticity while decreasing its plasticity, or tendency to flow.

Latex thread is very elastic as you can see and is used in making the inner windings for golf balls. When it is covered with cotton or other textile materials the thread can be knit or woven into elastic fabrics for making a variety of products such as swim suits and elastic support hose.

The latex thread was contributed by Fulflex Inc., Bristol, R.I.

Experiment 7. With a toothpick spread a thin film of latex over a one-inch area on a small piece of cotton or other fabric. Do not rub the latex in because it will coagulate and form lumps. Place another small piece of material over the latex pressing it down smoothly over it. Allow the latex to dry completely, then place a drop of water on the area. Does it penetrate the cloth?

One of the most useful properties of rubber is its impenetrability to water. Rubber boots, hot water bottles and rubber tubing are common products that take advantage of this property. The first

patented use of rubber was in the production of a waterproof fabric. In 1823, a Scotsman named MacIntosh obtained a patent for his invention which consisted of sandwiching a layer of rubber between two pieces of cloth, and raincoats made of this type of fabric were called macintoshes.

Experiment 8. Spread a thin film of latex with a toothpick over the surface of an object having an irregular surface, such as a button or key, allowing the latex to sink into the grooves. Set it aside and let it dry completely. Then gently remove the film very carefully. Does the film retain the contours of the surface?

Natural latex faithfully reproduces any indentations or markings of a surface on which it is dried. If the film is then vulcanized, the impressions can be retained and stretching and flexing will not change them. Latex thus can be made into flexible molds for use with such materials as cold setting resins and plaster of paris. The molds are usually made by dipping the object to be reproduced in latex in which vulcanizing ingredients have been mixed. After coating, the object is placed in an oven to vulcanize the latex. The rubber mold thus formed is flexible and can be readily removed.

Experiment 9. Blow up your balloon

noting how much it can stretch. Now release the air and note that it returns to its original size. Toy balloons are all made of natural rubber. Larger balloons are also made for weather and other meteorological observations.

The latex used for making balloons contains vulcanizing ingredients. The rubber particles in the mixture are very tiny and cannot be more than one micron ($1/1000$ millimeter) in size. If the particles are coarser, defects can occur in the product.

The molds for the balloons are dipped into the latex mix for a predetermined period and then withdrawn and dried in an oven at low temperature. The balloons are then vulcanized in a hot air oven.

Your balloon was contributed by the Ashland Rubber Products Co., Ashland, Ohio.

Experiment 10. Examine your specimen of foam backed carpeting which was provided by Mohasco Industries, Amsterdam, N.Y.

Bend it and note how flexible it is. Push down on the carpet and observe the cushioning effect provided by the latex foam. Squeeze one corner between your fingers and then release it. It can be compressed but immediately returns to its original thickness when the pressure is removed.

These properties of resilience, elasticity and flexibility result from the thousands of tiny cells filled with air incorporated in the latex. With a magnifying glass look closely at the surface of the latex foam and you will see the many tiny cavities. The cellular structure also makes the material very light weight.

Foam rubber is produced by beating air into latex to which vulcanizing ingredients have been added. The process causes the latex to froth forming many tiny bubbles. The frothing step is carried out under carefully controlled conditions. It is during this stage that the density of the final product is determined. A gelling agent is added to the frothing mixture to fix the cell structure. The foamed latex is then cured with steam.

To make foam backed carpeting an adhesive is applied first to the underside of the carpet and then the latex foam bound to it by the adhesive.

Foam backed carpeting is a rapidly growing industry and now about 42% of all the natural latex imported is used for this purpose.

In the mixtures for making high density foam, synthetic rubber is combined with the natural latex to achieve desired properties. The proportion of synthetic to natural latex and the kind of synthetic latex used varies widely

depending upon the manufacturer.

In addition to its uses for dipped goods (gloves, balloons), adhesives, thread and foam, latex has many nonrubber uses. For example, it is mixed into asphalt for road surfaces to provide longer wear and higher safety, added to soils as a stabilizer against erosion and used as a base for paints.

Synthetic latex is now widely used and has displaced the natural product in many areas, but for many purposes natural latex is still preferred because of its fast drying rate, wet tack and shorter vulcanization time. Also its solid content is higher with less viscosity and the film from raw latex has greater strength than that of synthetic latex. In many products made with synthetic rubber, such as rubber tires, natural rubber is always incorporated in the mixture to achieve superior quality, such as better adhesion of tire components, lower heat build-up, resistance to fatigue, cutting and chipping resistance.

The most important aspect of natural rubber production, however, is that the basic material, polyisoprene, is a product of nature, created in the normal course of plant growth, while synthetic latex is manufactured from petrochemicals, from a natural resource that is being rapidly

depleted because of its many diversified uses.

Rubber trees can be replenished by new plantings as needs arise. Its process is replacement rather than depletion. The rubber trees not only contribute latex to society, but also provide all the valuable effects on the environment related to plant life.

The main obstacle to natural rubber as the primary source of rubber is economic. Synthetic rubber is generally cheaper. Thus, the basic objective of natural rubber producers is to achieve greater yield at less cost. Much research is being carried on with this in mind. Higher yield trees have been developed and better methods of processing and transporting the raw rubber are being devised. These factors are rapidly making natural rubber price-competitive with general purpose synthetic rubbers.

STANDARD MALAYSIAN RUBBER

Experiment 11. Pour the remaining latex into a shallow dish and then slowly add an equal amount of vinegar (acetic acid) to it while stirring. What happens? Does the latex coagulate into a solid lump? Wash the coagulated material and dry it. Note its appearance. Is it elastic and flexible? Does it bounce when dropped?

This latex coagulum is like the product obtained at rubber collection centers after the liquid latex has been treated with weak acid. The coagulating tanks in which the latex is mixed with the acid are rectangular in shape and form continuous slabs of the coagulated latex which is then made into ribbed smoked sheets (RSS) or crumbed.

Experiment 12. Look at your strip of ribbed smoked sheet, noting its color and texture. Smell it. Does it have a smoky odor?

To produce this material, the continuous sheets of coagulated latex are washed and passed through ribbed rollers to squeeze out the water. The sheets are pressed to about 1/8 inch in thickness.

Notice the ribbed design and the thickness of your sample.

The thin sheets are next cut into suitable lengths and placed on racks. After most of the water has dripped off the sheets, they are taken to the smokehouse and drying room. Here the sheets are smoke dried with wood smoke. The process takes two to four days. After drying the sheets are visually graded according to their appearance.

Experiment 13. Cut two pieces from your RSS specimen about 1/2 inch wide. Stretch the pieces and notice their elasticity. Bend them and twist them noting

their flexibility.

Now place each piece on a sheet of aluminum foil. Put one in an oven heated to about 300°F. After about five minutes remove it and see how sticky it has become. Is it still elastic?

Put the second piece in the freezer and allow it to stay there overnight. Has it become hard and less flexible?

RSS has not been vulcanized so its plasticity changes with temperature.

The natural coagulum collected from various sources is combined and blended and then washed and passed through creping rollers. The creped sheets are then cut into convenient lengths and dried in large sheds. Drying takes several weeks. The dried crepe is separated into different grades depending upon the quality of the original material.

The crepe soles of sports shoes are made from creped pale raw rubber and are unvulcanized.

For many years the smoked sheets and crepes were the staple dry raw rubber. But with the development of high-yielding trees and the increase in demand, these forms of rubber were too variable and a better method of producing marketable raw rubber became necessary. Also, the need to modernize the grading system became more and more evident.

Thus, the Standard Malaysian Rubber

(SMR) scheme was devised and established in 1965. The SMR scheme is a new grading method of technical specifications which makes it no longer necessary to produce rubber in the form of sheets. New processes for preparing dry rubber were developed in which the coagulum is converted into granular form rather than into sheets. Granules can be more easily washed and are faster drying because of the increased surface area, taking only hours instead of days to dry.

The raw rubber can be granulated by a number of methods. After the latex is coagulated the coagulum can be cut with rotating knives or a crumbling agent may be added to the sheets of rubber being passed through the sheeting machine. The product of the latter method is called Heveacrumb and is a process widely used in Malaya. The crumbs are compressed into 75-pound bales, approximately 7 x 14 x 28 inches in size, then wrapped and sealed in polyethylene film.

Experiment 14. The crumbs or sheets are compressed under high pressure into bales of various sizes and shapes according to the customer's specifications.

Examine your specimen of SMR in the plastic bag. This is a specimen of the dry rubber that is compressed into bales of SMR. Note its light yellow color and

texture. The "5L" on the envelope indicates SMR grade 5, light color.

Although smoked ribbed sheet like your specimen is still produced, it is being gradually replaced by crumbed rubber. It is expected that within 10 years or so, practically all the dry rubber will be made by the new method.

The final stage of raw rubber processing, whether the dried product is produced by the old or new method, is baling under compression. The product is graded according to source and freedom from impurities as well as physical properties as color and plasticity.

The smoked sheet (old method) and the crumbs (new method) give you an idea of how these materials look before baling. The two specimens were contributed and especially prepared for this unit by the Rubber Research Institute of Malaysia (RRIM).

RUBBER PROCESSING

The dry rubber compressed into bales is shipped to the rubber companies for processing into various applications. First the solid bales of rubber must be cut into smaller workable pieces. When the granules like your specimen are compressed into bales, the result is a very firm and solid material that requires special saws or hydraulic slicing machines

for cutting.

The pieces of cut rubber are put into a mixer to soften and plasticize. Plasticizing chemicals may be added to accelerate this process, known as mastication.

When mastication is completed, various ingredients are added to the softened rubber to provide the characteristics desired in the final product. Vulcanizing chemicals may be added at this time as well as reinforcing or extending fillers to give the rubber special physical properties such as tear and tensile strength and abrasion resistance. The added ingredients must be thoroughly and uniformly dispersed throughout the rubber.

Many types of fillers are used, but the most important is carbon black.

Experiment 15. Look at your specimen of black tire carcass. The color is due to the presence of carbon black. Carbon black greatly increases the mileage of tires by enhancing its tensile strength, cutting and chipping resistance and resistance to wear, and is used in all tires. The tire carcass was contributed by the Goodyear Tire and Rubber Co., Akron, Ohio, and the B. F. Goodrich Co., Akron, Ohio.

If the blue plastic protective film is still attached remove it.

Experiment 16. Look closely at the tire carcass and you will see that it is formed of fabric coated and impregnated with rubber. Examine the piece from an angle and you will see the impression made by the threads on the rubber. Look along the cut edge and you will see the ends of the threads of the fabric.

The carcass is made by squeezing the rubber firmly onto the fabric by means of calenders. Calenders consist of three or four rollers placed one above the other parallel to each other. The rubber is applied to the cloth and is squeezed into the threads penetrating them as the material passes through the rollers.

Stretch the tire carcass. Notice that it stretches easily in one direction but not in the other. You will understand why if you observe the carcass as you pull on it. Does it shrink again after it is stretched?

Experiment 17. Feel the tire carcass. Is it sticky? This material has not been vulcanized. Notice that it is not very elastic. Compare its elasticity with that of your rubber band. Note how the rubber band snaps back, after stretching, while the tire carcass slowly shrinks but does not return to its original size.

Most automobile tires have two to

four layers or plies of tire carcass or cord. These layers of rubber-coated carcass are placed one on top of the other so that the cords of each layer are at angles to the adjacent layers, to provide greater strength and dimensional stability.

Experiment 18. Cut the tire carcass into four pieces and stack them in a pile with the threads in alternate layers at right angles to each other. Place the stack between two pieces of aluminum foil and then press it with a very hot iron while applying pressure for several minutes.

Allow it to cool and then examine it. Note that the thermal treatment has fused the four layers together and that the surface is no longer sticky. The pieces have become strong and hard. You have vulcanized the rubber carcass.

In the tire carcass the mix contains the necessary materials for crosslinking and so heating results in vulcanization.

Experiment 19. Stretch your rubber band and look at its complete length. You will see no end or beginning. This is because it is produced by the method known as extrusion.

The rubber compound for the rubber band is passed through an extruder that has a die at one end. As the rubber passes through it, it takes the shape and size of the die. When it emerges, it is

cut into the desired width. The rubber bands are then heated and vulcanized.

Many objects are extruded, such as garden hose and rubber tubing.

Because of its elasticity and strength natural rubber is usually used to make rubber bands.

The rubber bands were supplied by Arrow Rubber Products, Derby, Conn.

You have observed the properties of natural rubber that make it a most versatile material. Its uses enter into practically every aspect of our lives—from kitchen to laboratory, automobiles to hospitals.

Look around your home and you will find a surprising number of objects containing rubber. Count how many parts in your automobile make use of rubber.

Scientists and technologists are continually looking for ways to improve the raw material as well as the final product. Along with their research for making a better product they consider the effects of their methods on the environment.

Before World War II all the rubber in the world came from natural sources. During the war, raw rubber became unavailable and synthetic rubbers were developed. Natural rubber alone could not keep pace with post-World War II total demand for rubber, and now about 65% of the total rubber production is man-

made. However, with improved species and other means of inducing output of more natural rubber, natural rubber producers today believe they can supply a larger share of the world rubber market. This would help minimize both the depletion of petroleum resources and the ecological pollution attendant production of synthetic rubber.

The story of rubber goes back to the time of primitive man, but with research and development its story is always new. If you wish to study the subject further, references below will be helpful.

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Information on natural rubber and the materials contained in this unit may be obtained by writing to The Malaysian Rubber Bureau, Publications Office, 1108 16th Street, N.W., Washington, D. C. 20036.

Appreciation is expressed to the Malaysian Rubber Bureau/USA for their cooperation in producing this unit and to the various companies that participated in its preparation.

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